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NATIONAL ACADEMY OF SCIENCES. REPORT OF THE WATSON TRUSTEES ON THE AWARD OF THE WATSON MEDAL TO SETH C. CHANDLER.

ON the recommendation of the Board of Trustees of the Watson Fund, the Academy last year unanimously awarded the Watson medal to Seth C. Chandler, of Cambridge, Mass., for his investigations relative to variable stars, his discovery of the period of variation of terrestrial latitudes, and his researches on the laws of that variation. It is the pleasant duty of the Trustees to set forth the grounds on which this award was recommended.

It is a result of the well-known laws of dynamics relating to the rotation of a rigid body, as the earth is assumed to be, upon its axis, that the poles of the earth may be determined in two ways. Our globe, being a spheroid flattened at the poles and protuberant at the equator, has a certain axis passing between the points of greatest flattening. This axis has no direct connection with the rotation of the earth; it would exist if the latter, retaining its present form, did not rotate at all. It is called the axis of figure, being determined altogether by the shape of the earth.

But the earth has also an axis around which it rotates. Now, assuming the earth to be a rigid solid, there is no necessity that the axis of rotation should correspond to that of the axis of figure just described.

We could take a solid body, pass an axis through it in any direction, and make it rotate on that axis.

It was shown by Euler, more than a century ago, that if a solid body rotated on an axis different from that of figure, the position of the axis of rotation in the body would be subject to a slow change, consisting in a constant revolution around the axis of figure. Were this body the earth, the latitude of a place, as determined by astronomical observation, would change in the same way. The time of one revolution of the pole would depend upon the figure of the earth. The flattening of the earth is such that, were it a perfectly rigid body, the time of revolution would be about 305 days; that is to say, the north pole would make its circuit in a period of 305 days.

There being no necessity that the two poles should coincide, the question was naturally raised whether, perhaps, there might actually be such a difference of the two poles, and, in consequence, a change of latitude of every place on the earth's surface having a period of 305 days. The first to investigate this question with all the refinements of modern astronomy was C. A. F. Peters, who, half a century ago, was an assistant at the Pulkowa Observatory. In his classic paper on the parallax of the fixed stars, one section is devoted to the question of the variability of the latitude in a period of 304 days, which, according to the then accepted value of the flattening of the earth, would be the time of one revolution of the poles. He found a coefficient of 0″.079, with a probable error of 0″.017. This result was so extremely minute that it might have arisen from unavoidable sources of error; and the conclusion therefore reached was that if there was any such separation of the two poles, it was too small to be certainly detected by the most refined observations.

In 1862 our late fellow member, Professor Hubbard, of the Naval Observatory, commenced a series of observations with the prime-vertical transit of that institution, which would be available for the same research. They were interrupted after a little more than a year, by his untimely death, but were continued four years longer by his successors. The result was the same as that reached by Peters; no change having a period of 305 days could be detected.

In 1873 the question was investigated by Nyrén in connection with a longer series of observations on the latitude of the Pulkowa Observatory. His results were somewhat discordant, and the only conclusion that could be drawn from them was that the variation could not be certainly detected by these most refined observations.

Ten years later Nyrén repeated the determination, in connection with his observations for the determination of the constant of abberation. These observations, made with the prime-vertical transit, were carried through with the minutest attention, and the utmost care to avoid every conceivable source of error. Curious discordances were nevertheless found in the results for the constant of abberation.

In 1885 Küstner showed that they could be accounted for by supposing a change going on in the latitude. But nothing could be inferred respecting the law or the cause of the change.

As a result of these investigations, the coincidence of the earth's axes of rotation and of figure has, until within a very few years, been assumed by astronomers as a practically established fact; and all their methods of observation have rested upon the idea of absolute coincidence. This confidence has not been disturbed until within a few years, when the question has been reopened. But it has now apparently been settled upon a new and firmly established basis.

Dr. Chandler's work upon this subject began with observations made by him in

1884–85, using a novel form of astronomical instrument of his own invention. These observations, continued uninterruptedly for thirteen months, revealed a progressive change of a pronounced periodical character in the instrumental values of the latitude. In publishing these results in 1885 he announced his intention to continue the research throughout the remainder of that year. Yet circumstances prevented him from carrying out his intention at that time, and he did not resume his examination of the subject until six years later. Meanwhile Dr. Küstner, at the Observatory of Berlin, in 1888, published a memoir on the Constant of Aberration, as deduced by him from a series of observations also made in 1884–85, simultaneously with Chandler's series, which brought to light anomalies of an entirely analogous character. Küstner's series was not continuous enough to show the periodic nature of the phenomenon; but, by an exhaustive examination of the possible subjective sources of error, he clearly demonstrated that it was no longer permissible to retain the hypothesis of an invariable position of the pole, and he recommended that properly organized observations at various places be instituted to settle the question definitely. It was doubtless this work of Küstner's which compelled the attention of astronomers to the subject. As a result, by the coöperation of three German observatories, under the auspices of the International Geodetic Association, and the independent action of that at Pulkowa, the fact of the variability of terrestrial latitude was placed beyond question, and, by a corresponding series made at the Sandwich Islands, the further fact was established that the variable element is the position of the axis of rotation with respect to the earth's body, and not its position in space.

It was just before this point that a renewal of Chandler's connection with the problem began. The results are published in a series of eighteen papers in the Astronomical Journal (1891–94), exclusive of a series of five papers upon a topic closely related thereto, and involving it; namely, the abberation-constant, which will be separately spoken of later.

The keynote of these investigations, and the undoubted cause of the success which has attended them, lies in the fact that at the outset he first recognized the neccssity of deliberately disregarding all teachings of the adopted theory, which had misled previous investigators, and of examining the facts by a purely inductive process, taking nothing for granted, and basing all conclusions strictly upon the observations themselves.

It is impossible to give here more than a bare statement of the principal results thus established, which we arrange in their natural order, and not in the historical order of their derivation.

1. The phenomenon is not a local or a regional, but a terrestrial one; also it is a displacement of the earth's axial rotation with reference to the principal axis of inertia, and not of the direction of the former in space.

2. The axis of rotation, although fixed as regards its direction in space, performs a relative revolution about that of inertia in a period of 428 days. This motion is circular, with an average radius of about fourteen feet, and its direction is from west to east.

3. Simultaneously with the above motion, the actual position of the principal axis of inertia on the earth's surface is in motion about a mean position, in a period of a year. Its direction is also from west to east, but is in an ellipse, three or four times as long as broad, the major and minor axes being about twenty-five feet and eight feet respectively. The major axis is inclined at present, by about 45° to the Greenwich

meridian. The motion is central, obeying the law of proportionality of times to areas described by the radius vector about the center of the ellipse.

4. Both the radius and period in the circular 428 days' revolution are systematically variable; the former between about eight feet and eighteen feet, the latter between about 423 and 434 days; in a long period of apparently about sixty-six years. In this inequality of motion the average angular velocity is attained when the size of the circle is least or greatest when the circle has its mean dimensions.

5. Similarly there are simultaneous changes in the apparent dimensions and velocity in the annual period, which are complementary in their character to those in the 428 days' revolution; but whether they are the result of real changes in the form and dimensions of the ellipse, or the effect of an apsidal motion of long period, cannot at present be determined from the observations available. All that can be said is that observations during five years show that the line of apsides is either fixed, or, if variable, revolving only at a very slow rate.

6. Besides these two motions of relatively short period, there is distinct evidence of a third motion of rotation in a much larger term, probably not far from twelve years, with a radius of ten or fifteen feet, which reconciles similar indications of slow changes which had been pointed out by other investigators. (A. J., XII., 178; XIII., 35, 36.)

The results thus established are the outcome of the examination of an immense number of observations, covering the whole interval since the era of refined practical astronomy began, and in fact practically exhaust the materials which may be drawn for this purpose from existing astronomical annals. The endeavor to make the discussion exhaustive in this respect made it necessary to completely reduce, from the original instrumental readings, extensive older series of observations. It has, incidentally, for example, rescued from almost complete oblivion the series of Pond, 1825–36, and shown that work to be of a character which will compare favorably with the most refined observations made with the meridian instruments of the present day.

Intimately connected with the work on the variation of latitude are five additional papers, containing a redetermination of the value of the aberration-constant from eight different series of observations at the Pulkowa Observatory, with the prime vertical transit and the vertical circle. The correct value of this fundamental element is one of the most important questions occupying the astronomy of the day.

VARIABLE STARS.

THE subject of variable stars was erected into a distinct branch of astronomical science by Argelander, beginning in 1843, and occupied a large share of his activity and interest during a score of years. His classical labors were succeeded or overlapped by those of Schönfeld, who assumed the principal charge of the subject for another score of years, when his devotion to the great work of the Southern Durchmusterung, and later his failing health, left opportunity for other hands to take up and continue the work where they had left it. Since the issue of Schönfeld's Second Catalogue the number of known variables has more than doubled, while the fund of observations pertaining to them has vastly increased. Chandler's work in this direction, besides the incidental work of observation and discovery which he has contributed to it, has involved the collection of all the data in astronomical history, their discussion, and the formulation of the elements of their light-variations into numerical laws. The catalogues of 1888 and 1893, while filling a

very moderate number of pages of print, are a crystallization of all the known facts. Especially may be mentioned the investigations of inequalities in the periods of these bodies. While the number of these inequalities known in Schönfeld's time amounted to only about half a dozen, Chandler has detected their existence in about eighty other stars, and has deduced the numerical laws in about fifty of them. This will indicate, in one direction only, how the labor of caring for these objects is increasing.

It would be unjust if, while alluding to these important researches, no mention were made of Mr. Chandler's ingenious and successful device of a new form of instrument for making that class of measurements of position which had previously been made by meridian instrument alone. Both the instrument and the method were novel. In the former, instead of a motion of rotation, determined mechanically by the pivots of a horizontal axis, there was substituted one about a vertical axis determined by gravitative action of an instrument resting in mercury.

As to method, instead of a vertical plane passing through the pole, which is the fundamental plane of reference for meridian instruments, there was substituted a horizontal circle. The value possessed by such an entirely different method consists in substituting a totally different sort of observation, and hence a different set of the systematic errors to which all observations are liable, so that the combined results of the two methods are likely to be freer from them than those obtained by an adherence to a single system of observation. In a memoir of 222 pages Dr. Chandler develops the theory of the instrument and method mathematically, and gives the result of its practical use in observations made with it for a year, and directed to various astronomical problems.

Although not mentioned as forming any part of the grounds for the award of this medal, Dr. Chandler's important labors for many years upon cometary orbits are well known to astronomers. Casual mention may be especially made of his computations relative to the principal component of 1889V, and the action of Jupiter in 1886 upon it, which led to a complete transformation of its orbit; also the definite determination of the relative orbits of the several components into which the comet became separated in consequence of that disturbance.

The Trustees of the Watson Fund feel that this brilliant series of investigations is preëminently deserving of the highest recognition which can be given by the National Academy, and have therefore not hesitated in recommending the award of the medal to Dr. Chandler.

S. NEWCOMB.
B. A. GOULD.
A. HALL.

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*SUMMARY OF CONCLUSIONS OF A REPORT BY DRS. D. H. BERGEY, S. WEIR MITCHELL AND J. S. BILLINGS UPON 'THE COMPOSITION OF EXPIRED AIR AND ITS EFFECTS UPON ANIMAL LIEE.'**

1. THE results obtained in this research indicate that in air expired by healthy mice, sparrows, rabbits, guinea pigs or men there is no peculiar organic matter which is poisonous to the animals mentioned (excluding man), or which tends to produce in these animals any special form of disease. The injurious effects observed of such air appeared to be due entirely to the diminution of oxygen or the increase of carbonic acid, or to a combination of these two factors. They also make it very improbable that the minute quantity of organic

* Results of an investigation made under the provisions of the Hodgkin's Fund. Read before the National Academy of Sciences, April 16, 1895, by permission of the Secretary of the Smithsonian Institution.